METAL VAPOR EXCIMER LASER

Quarterly Progress Report
for period November 1, 1978 - January 31, 1979

A. Mandl, J. Jacob and M. Kovacs

AVCO EVERETT RESEARCH LABORATORY, INC.
a Subsidiary of Avco Corporation
Everett, Massachusetts 02149

Contract No. ES-77-C-02-4275

March 1979

NOTICE
This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Department of Energy, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

prepared for

THE U.S. DEPARTMENT OF ENERGY
9800 South Cass Avenue
Argonne, Illinois 60439

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

ABSTRACT

Current and voltage characteristic measurements in room temperature Ne and high temperature ($T \sim 550^\circ\text{C}$) Cd/Hg/He mixtures are described. Initial gain/absorption measurements have been inconclusive.

Some discussion is also included on technology problems associated with component survivability which have been encountered, e.g., failure of quartz to metal seals and rapid oxidation of Cu magnet windings at elevated temperatures. The approach used for solving these problems is outlined.

TABLE OF CONTENTS

<u>Section</u>	<u>Page</u>
Abstract	ii
I. INTRODUCTION	1
II. EXPERIMENTAL APPARATUS	2
III. MEASUREMENTS AND DISCUSSION	6
A. Discharges	6
B. Gain	10

I. INTRODUCTION

The apparatus for making gain/absorption measurements in HgCd* has been assembled and run at 550°C for several days during which energy was deposited by the e-beam and discharge into the gas. Some initial gain/absorption measurements have been performed using an Ar ion laser as a probe to check out the procedure.

Running the system at 550°C for extended periods caused some apparatus problems. The quartz to metal seals deteriorated and the Cu magnets oxidized rapidly. Some work has begun on correcting these technology problems in order to allow longer run times without system failure.

II. EXPERIMENTAL APPARATUS

A schematic diagram of the experimental cell used for the gain measurements is shown in Figure 1. The discharge tube is made of quartz. A 550 kV Febetron is used to preionize the gas with a 30 nsec, 1000 A pulse. The magnets are used to guide the preionizing Febetron pulse down the tube. An oven is used to heat the tube and magnets to 550°C in order to maintain the necessary vapor pressure of the Cd in the Ne, Hg, Cd mixture. It has been shown that a discharge which is not sustained by an e-beam cannot be stable. The instability will either lead to a volumetric increase in ionization, which can result in an arc breakdown, or, depending on the level of preionization and the discharge voltage, can lead to a decay in the current due to electron-ion recombination.

We are interested in running the discharge in a quasi-stable mode before these instabilities occur. It is for this reason that a crowbar circuit has been added which will be timed to turn off the discharge before arcing can occur. Since arcing can cause damage to the discharge tube, an additional ballast resistor is being added to current limit any breakdown. Arcing is also to be avoided since it produces a large increase in electron density which may quench the HgCd*.

Figure 1 Schematic Diagram of Discharge Tube

A schematic diagram of the improved discharge/crowbar circuit is shown in Figure 2. The initial tests of this circuit have indicated some problem with reliability of firing the crowbar spark gap. This problem is presently being addressed.

Other technical problems currently being addressed are those associated with the high temperature environment of the experimental apparatus. The molybdenum to quartz seals used for the discharge tube feed-throughs have not held up under long term use. We have recently coated similar seals with a fused silica adhesive and heated them in an oven at 550°C for several days. The coated seals showed no significant deterioration during this period, whereas, uncoated quartz to molybdenum seals showed significant deterioration. This approach offers considerable promise.

Another problem encountered is the rapid oxidation of the Cu magnets. We are therefore making a new set of magnets which are Ni coated using oxygen free (OFHC) Cu. These should be far more resistant to high temperature oxidation.

H8882

Figure 2 Schematic Diagram of Discharge Circuit with Crowbar Trigger

III. MEASUREMENTS AND DISCUSSION

A. DISCHARGES

A series of oscilloscope traces in Figure 3 shows the measured current and voltage characteristics of the preionized discharge of pure Ne as a function of applied field. The total discharge length is 40 cm and the neon is at room temperature and a pressure of 340 torr. For comparison, the top oscillogram was for no Febetron preionization pulse. In this case when the 20 kV voltage is applied very little current is drawn. The gas does eventually break down after $\sim 1.5 \mu\text{sec}$, then the current initially rises (250 A/div for this trace), the .01 μf capacitor drains, the voltage decreases, and then the current decreases.

In the other traces the current turns on shortly after the Febetron fires. At low fields, the current dies away leaving the storage capacitor charged. At increasing electric fields, the discharge current increases passing through a narrow range of relative stability ($V_{\text{DC}} \sim 23 \text{ kV}$) and finally decays because the capacitor is drained and the voltage decays. At the higher fields ($V_{\text{DC}} \sim 25 \text{ kV}$), the discharge rapidly goes unstable and it is only because the capacitor is small that an arc does not develop.

Current and voltage discharge characteristics were measured for a Cd/Hg/Ne mixture at 500°C for various applied voltages.

H 77 37

Figure 3 Current/Voltage Characteristic Measurements in Pure Neon (P = 340 torr) as a Function of Discharge Voltage

Oscilloscope traces of these I/V characteristics is shown in Figure 4. These show a steadily decreasing region of quasi-stability as the applied dc voltage is increased from 20 kV to 23 kV. Again because of the choice of a .01 μ f capacitor arcing is prevented. Even at the highest voltage, a quasi stable is achieved for $\sim 1 \mu$ sec. With a crowbar applied at that point a nice stable 1 μ sec pulse would be achieved. The pressures of the Cd, Hg and Ne were measured directly using a high temperature pressure probe and indicated $[Cd] = 1.4 \times 10^{16} \text{ cm}^{-3}$, $[Hg] = 1 \times 10^{18} \text{ cm}^{-3}$ and $[Ne] = 6.3 \times 10^{18} \text{ cm}^{-3}$.

One problem which these measurements showed is that the initial current into the discharge is low. Comparing the energy observed in the discharge with the energy necessary to produce $HgCd^*$, we have

$$iV\tau = [HgCd^*] \epsilon_{Cd^*} \frac{1}{\eta} A l \quad (1)$$

where i is the discharge current, V is the discharge voltage, τ is the discharge pulse length, ϵ_{Cd^*} is the energy to produce a Cd^* , η is the efficiency of making $HgCd^*$ from Cd^* (taken to be 0.5) and Al is the volume of the discharge. One can calculate the density of $HgCd^*$ produced is $6.4 \times 10^{15} \text{ cm}^{-3}$. Thus, for a stimulated emission cross section of 2×10^{-19} one would expect at most a total gain length product, $g_0 l = 0.05$. For wavelengths not at the peak of the stimulated emission cross section, even lower values of $g_0 l$ would be expected.

H7806-I

Figure 4 Current/Voltage Characteristic Measurements for Cd:Hg:Ne Mixture for Several Applied Voltages; $[Cd] = 1.4 \times 10^{16} \text{ cm}^{-3}$, $[Hg] = 1.0 \times 10^{-18} \text{ cm}^{-3}$, $[Ne] = 6.3 \times 10^{18} \text{ cm}^{-3}$.

In order to increase the discharge current, a new alignment procedure will be employed in setting up the magnetic fields for the Febetron pulse. It is felt that this will substantially increase the Febetron current, and consequently the discharge current, and increase the density of HgCd^* produced.

B. GAIN

The gain/absorption measurements were attempted despite the expected small signals in order to check out the various components and observe any noise problems which might occur. A schematic diagram of the gain apparatus is shown in Figure 5. This is a standard gain/absorption setup. The electronically controlled shutter is used to reduce the exposure time of the photomultiplier tubes to the Ar ion cw laser beam before the discharge is fired. Optical fibers are used in conjunction with the photomultipliers which are physically removed to a screen room in order to reduce noise background relative to the expected small signals.

As an initial check, the Febetron was fired and the noise gain channel observed as shown in Figure 6. The short lived pulse should not significantly limit the gain measurements after $1/2 \mu\text{sec}$ since the primary region of expected gain is in the after-glow at times just after the crowbar is fired and the various excited species, which could be absorbers at the laser wavelength, have decayed.

Figure 5 Schematic Diagram of Optical Gain Setup

GAIN CHANNEL D.C. LEVEL = 400 mV

NOISE CORRESPONDS TO 5% "GAIN"

H7738

Figure 6 Febetron "Pickup" on Gain Channel

Figure 7 shows oscilloscope traces of the I/V characteristics of a 20 kV preionized discharge in Cd:Hg:Ne at 550°C. The crowbar circuit was not yet installed for these experiments so that the discharge shows a volumetric instability. Arcing is prevented because the .01 μ f capacitor quickly drains.

The probe/reference oscillogram is on a slower 5 μ sec/div sweep and appears to show absorption. This "absorption" arises from thermal lensing. This was subsequently verified by increasing the acceptance angle of the optical detector and observing that the "absorption" disappeared. Under conditions of a wide acceptance angle no absorption or gain was observed.

Figure 7 Voltage/Current and Probe/Reference Measurements in Cd:Hg:ne Mixture for 20 kV Discharge Voltage Showing Apparent Absorption

DISTRIBUTION LIST

Dr. Paul W. Hoff (6 copies)
New Laser Programs Manager
Office of the Assistant Director
for Laser Fusion
Division of Laser Fusion C-404
U.S. ERDA
Washington, D.C. 20545

Dr. John L. Emmett
Associate Director for Lasers
Lawrence Livermore Laboratory
P.O. Box 808
Livermore, CA 94550

Dr. Roger B. Perkins
L Division Leader
Los Alamos Scientific Laboratory
P.O. Box 1663
Los Alamos, NM 87545

Dr. James B. Gerardo
Sandia Laboratories
P.O. Box 5800
Albuquerque, N.M. 87115

Dr. Donald Setser
Kansas State University
Department of Chemistry
Manhattan, Kansas 66505

Dr. H. Kidal
Massachusetts Institute of
Technology
Lexington, MA 02173

Dr. Nicholas I. Djeu
Code 5540
Naval Research Laboratory
Washington, D.C. 20375

Dr. Robert Center
Mathematical Sciences North-
west, Inc.
P.O. Box 1887
Bellevue, WA 98009

Dr. Ray Taylor
Physical Sciences, Inc.
30 Commerce Way
Woburn, MA 01801

Dr. William F. Krupke
Lawrence Livermore Laboratory
L-258
P.O. Box 808
Livermore, CA 94550

Dr. Gerald L. Rogoff
Westinghouse Electric Corporation
1310 Beulah Road
Pittsburgh, PA 15235